

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR LETTERS PATENT

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**METHOD OF CONNECTING A MULTIPLICITY OF OPTICAL
ELEMENTS TO A BASIC BODY**

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- 0001 The invention relates to a method of connecting a multiplicity of optical elements to a basic body, in particular for producing a faceted mirror. The invention also relates to a faceted mirror produced by the method.
- 0002 US Patent 4,277,141 discloses a method by which a multifaceted mirror is produced in several steps, to be specific individual mirrors are created in a first step, and the individual mirrors are subsequently fixed and aligned and are bonded to a supporting body by means of an adhesive.
- 0003 US Patent 4,195,913 discloses a faceted mirror in which a multiplicity of individual mirrors are adhesively bonded or screwed on a spherical support structure.
- 0004 In US 6,166,868 there is a description of an optical mount for an optical component, an inner part being connected to an outer frame by a plurality of resilient articulated bars. The resilient articulated bars are produced galvanoplastically.
- 0005 The present invention is based on the object of providing a method of connecting a multiplicity of optical elements of the type mentioned at the beginning, it being possible for the multiplicity of optical elements to be arranged on the basic body with high accuracy, in particular with respect to position and angularity, so that for example beam mixing and field imaging operations can be performed with high precision.

0006 The present invention is based on the object of forming a faceted mirror with a multiplicity of individual optical mirror elements which produces a homogeneous lighting distribution or homogeneous illumination and very exact beam mixing and field imaging.

SUMMARY OF THE INVENTION

0007 The object is achieved according to the invention by the method given in the defining clause of claim 1. A faceted mirror produced by the method according to the invention is described in claim 12.

0008 By the method according to the invention, a multiplicity of individual optical elements, which may be of a completely identical form, can be connected to one another and to a basic body in a relatively simple way and very precisely by the galvanoplastic process. Since exactly reproducible conditions are created by the galvanoplastic process, in this way it is possible for example to form a faceted mirror which permits the homogeneous illumination of a field, thereby making correspondingly good beam mixing and exact field imaging possible.

0009 With the method according to the invention, a beam mixing or lighting which eliminates the disadvantageous higher light intensity in the medium range is achieved. This is of advantage in particular in optical lithography with an EUV lighting system, in which for example it is desirable to have on the reticle (mask) a homogeneously illuminated area that is as large as possible.

0010. It is possible for the method according to the invention to be realized by two production principles:

0011 1. The optical elements may be connected to the basic

body by a galvanoplastic joining technique, in which the basic body may also be galvanically formed.

0012 In the case of galvanic forming of the basic body, the latter is created in such a way that it includes the position of the facets, but not their surface quality, on the supporting body. The required surface quality is then realized by the optical elements, for example mirror elements, which after placement on the basic body are connected to the latter by growing together galvanically. The galvanic connection achieves not only precise, full-area and consequently very exact positioning and connection but also very good heat conduction for the rapid heat removal from the mirror elements into the basic body.

0013 2. On an auxiliary structure which represents the negative form of the optical part to be produced, for example of a faceted mirror, the optical elements are for example fixed by an adhesive or a resin, in the production of a faceted mirror from mirror elements their mirrored sides being directed toward the auxiliary structure. In this case, the exact position and alignment of the optical elements is defined by the auxiliary structure. By this type of fixing, the optical surfaces directed toward the auxiliary structure, such as for example the mirror surfaces, are also protected from contaminants during the subsequent galvanoplastic process.

0014 As soon as all the elements have been brought into position, the complete unit is cathodically connected in a bath and the optical elements are bonded into a body which is building up or growing up.

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- 0015 If lenses are used as optical elements, they are fixed on one of the optical surfaces. The second optical surface must in this case then be separately protected from contaminants. Lenses or nonconducting mirror elements must be made electrically conductive in advance by a corresponding coating.
- 0016 In advantageous developments of the invention, it may be provided that cooling and/or reinforcing devices are incorporated into the growing body during the galvanoplastic process.
- 0017 The method according to the invention forms virtually a monolithic body which, by good heat transfer of the individual optical elements to the basic body, makes efficient cooling of the optical element possible.

BRIEF DESCRIPTION OF THE DRAWINGS

- 0018 Further advantageous refinements and developments of the invention emerge from the subclaims and from the exemplary embodiments described in principle below with reference to the drawing, in which:

figure 1 shows a basic representation of a faceted mirror according to the invention, arranged in an EUV lighting system for microlithography,

figure 2 shows a first method of production for a faceted mirror,

figure 3 shows a second method of production for a faceted mirror, and

figure 4 shows a basic body for a faceted mirror with reinforcements in a honeycomb structure and with cooling channels.

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- 0019 A method of producing a faceted mirror and a faceted mirror produced by the method are described by way of example below. In principle, however, the method is also suitable for connecting or joining together other optical elements, such as lenses and lens arrays for example. In figure 1, the use of a faceted mirror 1 in a lighting system for EUV lithography is represented. The light of a source 2, for example of a laser, is cast via a collector mirror 3 onto the faceted mirror 1, where it is fed with the desired uniform illumination via a deflecting mirror 4 to a reticle (mask) 5. The pattern of the reticle 5 is passed via a projection lens system 6 not represented in any more detail to a wafer 7 for the imaging of the image of the reticle 5.
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- 0020 The production of the faceted mirror 1 with correspondingly high precision and homogeneous or as-desired illumination takes place according to figure 2 on a basic body 8. The basic body 8 may be formed for example by galvanic means, its functional surface corresponding with respect to curvature and position to the requirements which the finished faceted mirror 1 has to meet. Only the surface quality is still lacking. The surface quality is then realized by individual mirror elements 9 as optical elements.
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- 0021 In the case of the present invention, as a modification of normal galvanofforming, a multiplicity of mirror elements, for example 200 to 300 elements, are produced in advance by a conventional production process, such as milling, grinding and polishing for example. A multiplicity of identical mirror elements are subsequently brought into position and alignment on the basic body 8 and then connected to one another by a

following galvanoplastic process. In this way, a faceted mirror is finally obtained as virtually a single monolithic part in an extremely precise form.

0022 By producing many identical mirror elements, the production of a faceted mirror is also facilitated, simplified and reduced in cost. Mirror elements of poor quality can be segregated in advance, or mirror elements 9 which are identical or virtually identical, in particular with respect to their optical properties, may be selected.

0023 Galvanoplastic processes are generally known, for which reason they are not discussed in any more detail here. In principle, this takes place by the mirror elements 9 being brought into their position on the basic body 8 and the entire unit then being cathodically connected in an electrolytic bath and the desired material, for example Cu or Ni, being used as the anode, so that the parts can grow together to form one unit. In this way, for example, the growing on of a copper layer of any desired thickness can be achieved.

0024 In principle, all conductive materials or materials which can be made conductive by coating come into consideration as materials for the mirrors. For EUV lighting systems, it should also be ensured that polishing to the required surface quality (0.2 to 0.3 nm RMS) is possible. In addition, the material should have good heat conductivities. For the reasons mentioned above, copper coated with nickel is generally used as the facet material.

0025 The mirror elements 9 placed on the basic body 8 are connected to the basic body 8 by a galvanoplastic joining technique, as indicated by an intermediate layer 10 between the mirror elements 9 and the basic body 8.

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- 0030 It can be additionally seen from figure 4 that the supporting structure 14 may be provided with a cooling system in the form of cooling channels 16.
- 0031 The cooling channels 16 can be formed during the galvanoplastic process. For this purpose, it is only necessary to provide corresponding wax inserts in serpentine form, these inserts subsequently being melted out.
- 0032 A further solution may comprise placing a copper tube on in a serpentine form and then allowing it to grow in during the galvanoplastic process. In this way, a very good heat transfer is then obtained on account of metallic bonding.
- 0033 It goes without saying that combinations are also possible. The same applies for example to the forming of the supporting structure 14 with the honeycomb structure 15, into which cooling channels 16 may likewise be formed, or else the honeycombs themselves may serve for cooling.